Energy Efficient Ultra-low NOx Burner (ULNB) Control Technology

Food Industry Energy Research (FIER) RD&D Project Review

University of California, Davis

October 26, 2004

Project Objective and Need

- **Project Objective**
  - Reduce Ultra-low NOx Burner (ULNB) Power Consumption by 25%
- **Project Need**
  - Severe ozone non-attainment in San Joaquin Valley
  - New AQMD rule requires boiler retrofits to 9 ppm NOx starting in 2005
  - Significant hardware and operating costs to achieve 9 ppm affect food processors

ALZETA Products

DURATHERM ™
OEM Residential/Commercial Low NO_X Burners

CSB ™ & CSB microSTAR ™
Industrial/Commercial Ultra-Low NO_X Burners

EDGE™
Catalytic and Thermal Oxidizers

CSB™ Ultra-Low NO_x Burners

Advanced Combustion Clean Air Solutions for Industry

CSB microSTAR ™

Commercial Boilers and Process Heaters

2 – 14.7 MMBtu/hr

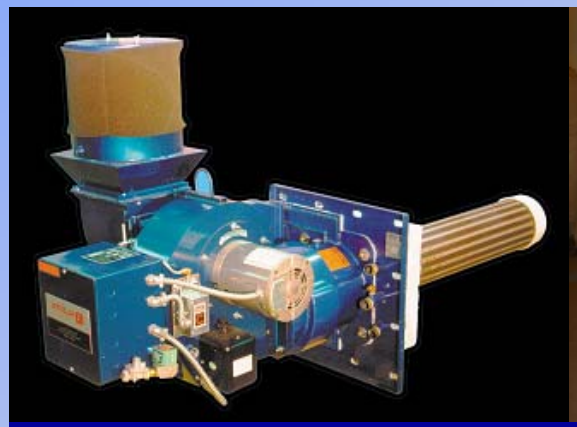
0.5 – 4 MW_t

CSB ™

Industrial Boilers and Process Heaters

16.8 - 130 MMBtu/hr

4 – 35 MW_t



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CSB Product Description

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- Fully Premixed Surface-Stabilized Burner
- All-Metal Burner Surface
- Surface Flux to 1.4 MMBtu/hr/ft^2
- Single Burners to 180 MMBtu/hr
- Optimized for Ultra-Low NO_x and CO Emissions

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CSB Burner Head

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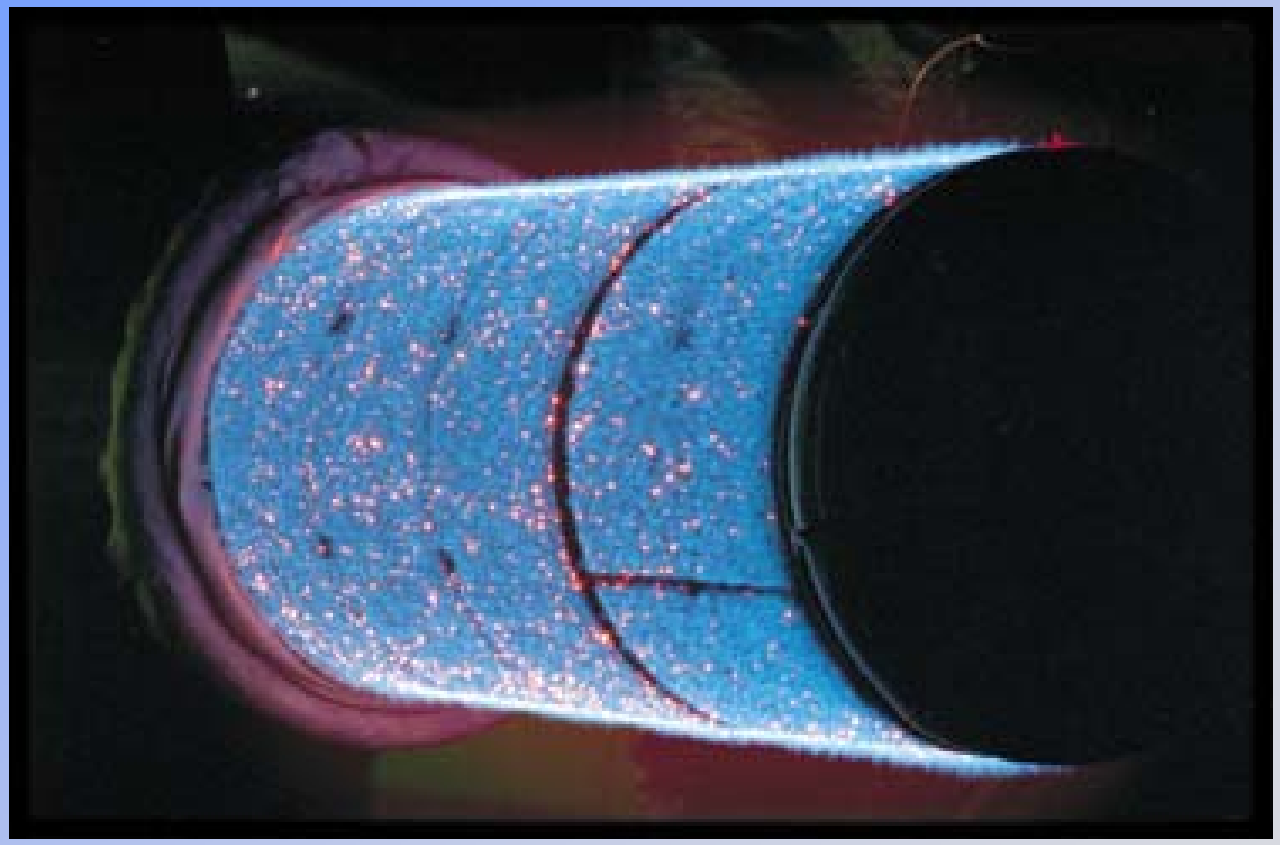

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How the CSB Works

- Premixed Combustion
  - Combustion takes place at uniform temperature
  - Flame temperature a balance between emissions and flame stability
- Surface Stabilization
  - Increases flame stability at lean limit
  - Increases heat transfer from flame zone

How Do We Control NO_x?

- NO_x is Primarily a Function of Flame Temperature
  - Flame temperature controlled by dilution of fuel-air premix with additional air or flue gas
  - Heat release rate and furnace design are secondary effects with CSB

CSB NO_x vs Excess Air

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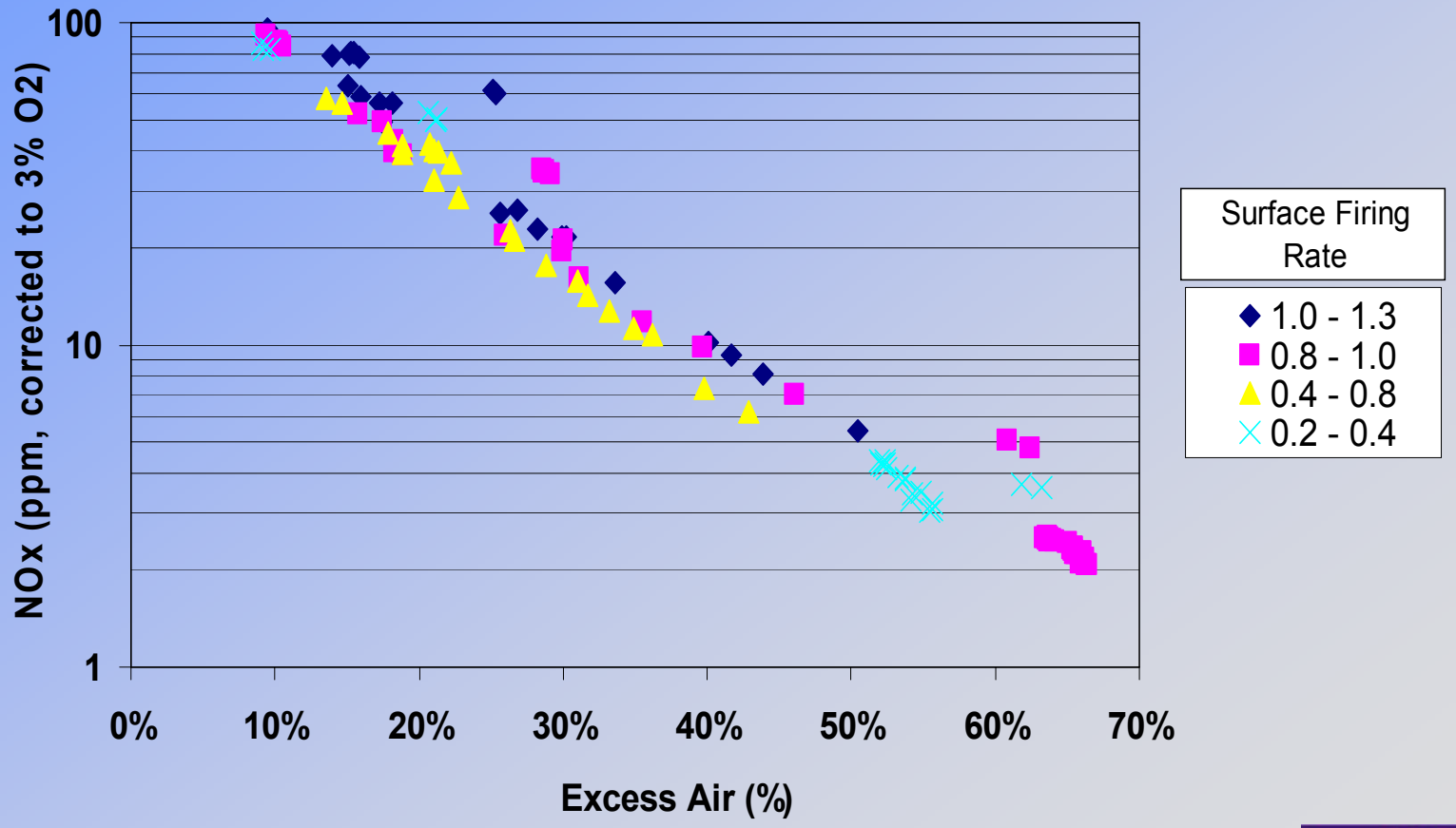

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High Efficiency CSB

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- NO_x Reduction with Low Excess Air
  - Flue Gas Instead of Excess Air Reduces Flame Temperature
  - Lower Flame Temperature = Lower NO_x
- Flue Gas Recirculation (FGR) Reduces Thermal Loss From Stack
  - Low Thermal Loss = High Efficiency

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CSB NO_x vs Total Dilution

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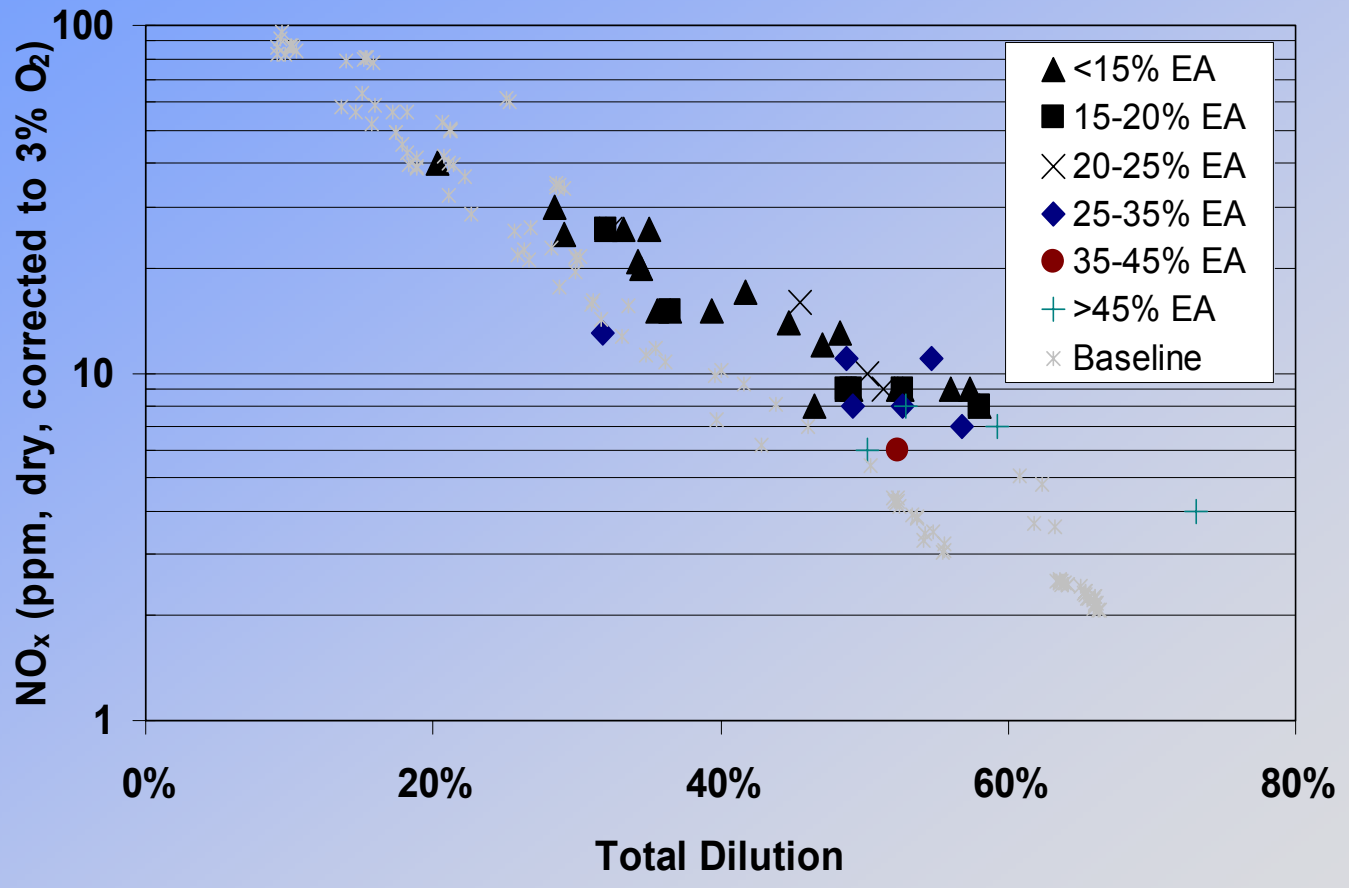

Burner and Fan Performance

- Burner Behaves as a Constant Mass Flow Device. Heat Input Proportional to Mass Flow of Air
- Fan Behaves as Constant Volume Device
  - For Fixed Density, Power Scales with Mass Flow Cubed! (dp x Q). Dilution requires more power.
  - Lower Density Air Requires Larger Housing and More Work for Fixed Mass Flow

Fan Power Issues

- Final 20% of Heat Input Requires 50% of Fan Power, Bigger Motors Use More Power at All Load Levels
- FGR Reduces Fuel Usage (Good)
  - Increases Mass Flow and Average Temperature of Diluent Through Fan
  - Therefore INCREASES Fan Size and Power Usage (Bad)

Improving Performance

- Fuel Component of Costs is Much Greater Than Electric Component
  - Doubling Fan Power has Approximate Cost of 1% Decrease in Thermal Efficiency
  - End Users Have Been Willing to Use More Power to Maintain Efficiency
  - But, Improvements Can Be Made!

Relative Fan Requirements

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NO_x Level (ppm)	Relative Mass Flow	Relative Volume (Inverse of Density)	Relative Fan Power	Fan hp for 50 MMBtu/hr Burner
100	1.0	1.0	1	25
30	1.15	1.09	1.80	45
9 (w/Ex.Air)	1.4	1.0	2.74	68
9 (w/ FGR)	1.4	1.22	4.08	102

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Fan Power vs Load

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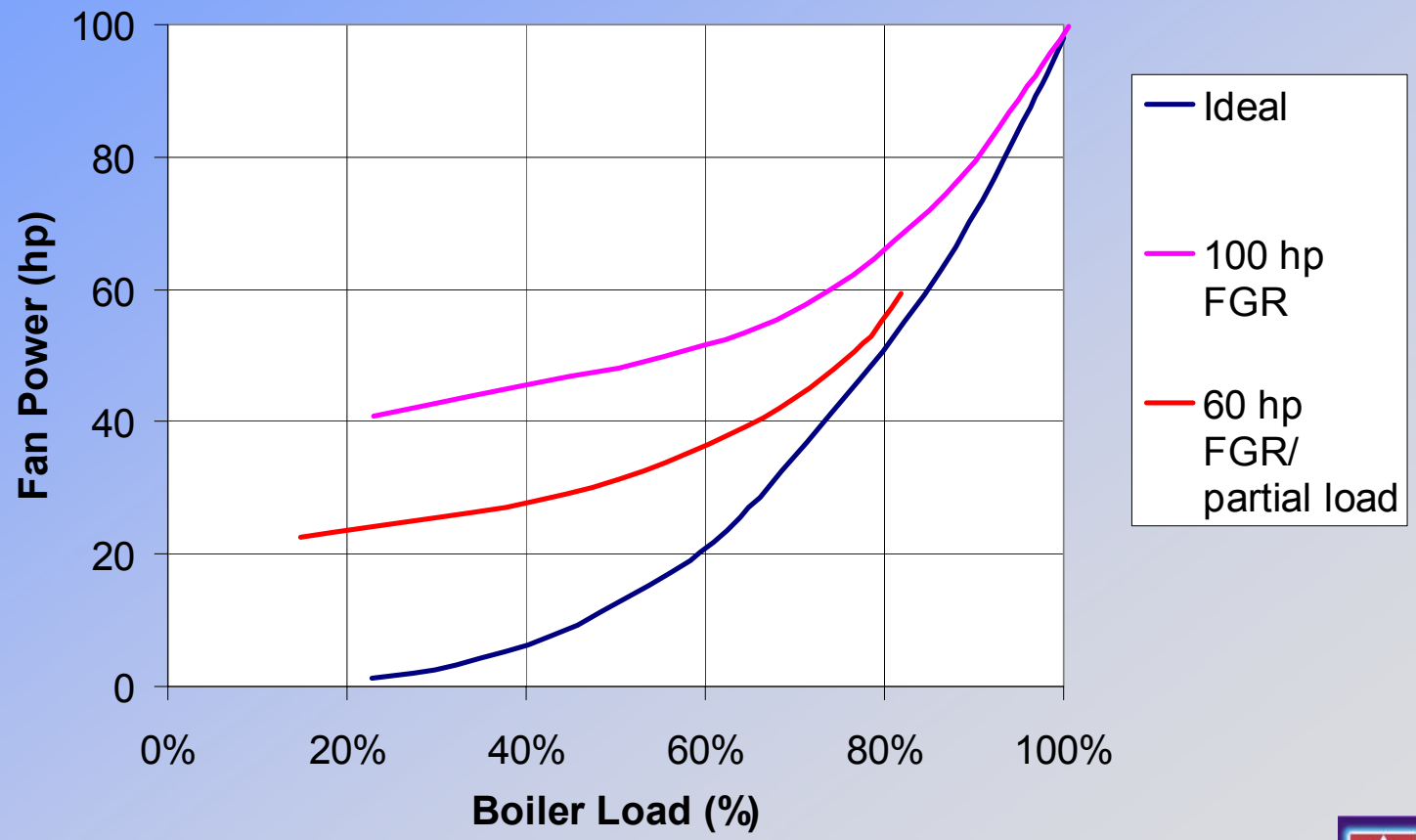

Improving Performance

- Fan Power Requirement Can be Reduced with Minimal Impact on Thermal Efficiency
  - Address Power Usage at Top 20% of Thermal Load Curve
  - Maintain Maximum Power Rating while Allowing Thermal Efficiency to Decrease at Maximum Input

Fan Power w/ EA and FGR

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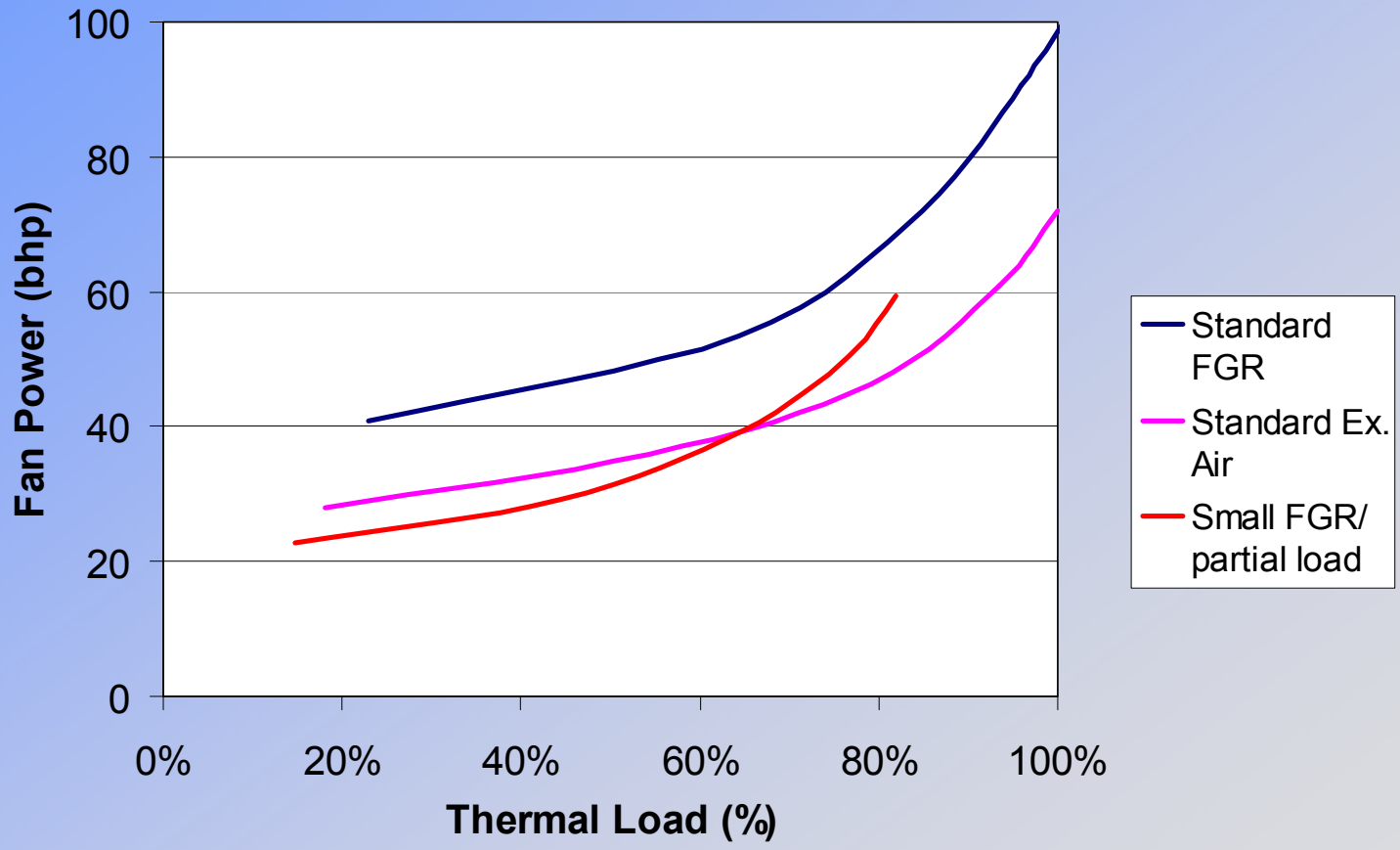

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Current Approach vs Hybrid

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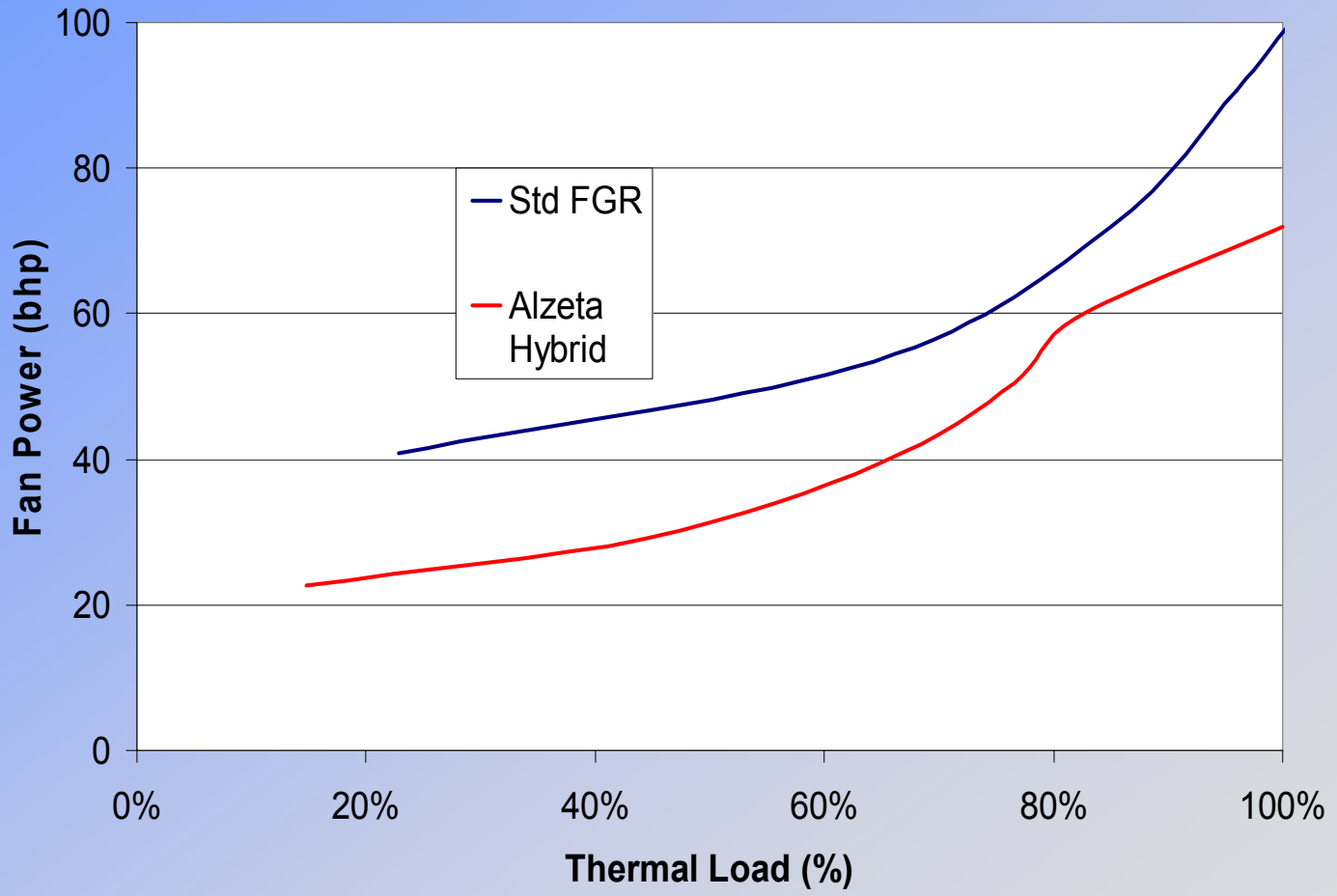

Implementation of Design

- Select Fan Housing and Motor for Excess Air Operation at High Fire
- Operate at Maximum FGR until “FGR Capacity” reached (~85% load)
- From 85-100% Load, Decrease FGR Fraction of Diluent, Increase Mass Flow

Implementation of Design

- Requires fuel-air ratio control modifications
  - Fixed fan-damper setting with variable fuel input
  - Control modification demonstrated prior to project start
    - Initially developed to track ambient air variation

End User Benefits

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Basis	Annual Operating Cost Savings ($.10/kWh and 25% average boiler usage)	Capital Cost Savings (25% lower cost of Alzeta fan)
Single User (50 MMBtu/hr burner)	$4,080	$3,000
San Joaquin Valley (SJVUAPCD Inv.)	$6,500,000	$4,800,000
State of California (Based on ARB Emissions Inventory)	$21,300,000	$16,000,000

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Reduction in Power Use

Basis	Reduction in Peak Demand	Reduction in Annual Energy Usage
Single User (50 MMBtu/hr capacity)	18.6 kW	340.8 MW-hrs
San Joaquin Valley (SJVUAPCD Inventory)	29.7 MW	65,300 MW-hrs
State of California (Based on ARB Emissions Inventory)	99.3 MW	217,400 MW-hrs

Summary of Benefits

- Reduced Initial Hardware Cost (Smaller Fan and Lower Amperage Power Hardware)
- Reduced Fan Power at All Load Levels. Power Savings at All Loads
- Increased Thermal Turndown

Package Watertube Boiler

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Industrial Firetube Boiler

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Demonstration Site

- 75 MMBtu/hr Package Watertube Boiler
  - Dairy Products Company Located in Central Valley
  - Installation in Progress for November Startup

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